Installations based on high efficiency high repetition rate miniature DPF chambers for material science

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Abstract The report describes two DPF installations based on a miniature plasma focus chamber: the installation PF-3 of the energy store W = 3 kJ and the installation PF-0.2 (W = 200 J). The possibility of an adaptation of the small DPF device for the experimental samples irradiation is reported. A new construction intended for experiments with samples of various materials is presented.

Key words dense plasma focus • miniature focus chamber • PF instalation

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Introduction

Dense Plasma Focus (DPF) installations just after the revelation of the plasma focus phenomenon by N. Filippov [3] and J. Mather [5] were based as a rule on the DPF chambers of rather big dimensions so the usual installation energy store is estimated in dozens or hundreds of kilojoules. For example, the P. N. Lebedev Institute DPF installation "TULPAN", by means of which the first series of the metallic samples was irradiated in accordance with INCO-COPERNICUS contract, has an energy store of about 60 kJ [4].

This report is entirely devoted to the discussion of the opportunity to apply DPF installations of a very small dimension scale to the COPERNICUS research problems and to some other applications.

PF-3 installation

The parameters of the PF-3 installation, which is being assembled in P. N. Lebedev Institute, are presented in Table 1. The installation ability to operate in a high efficiency mode is generally conditioned by a best standard quality of three of its elements: energy capacitor, commutator, and the DPF chamber. As an energy capacitor we use two high voltage low inductance condensers KMK-7-30 elaborated and manufactured specially for the class of installations under discussion by the Sankt-Petersburg Polytechnical University according to our joint work [1]. The capacitor parameters are presented in Table 2.

As a switchboard we use the thyratron with the cold cathode (pseudo spark switch) "EVOLUTA" type manufactured at

Table 1. Parameters of the PF-3 installation.

Energy store	W ≅ 3-4.5 kJ
Bank capacity	C = 14 μF
Charging voltage	U ≅ 20-25 kV
Maximal current	I ≤ 400 kA
1-st quarter-period	1/4T ≅ 1.3-1.5 μs
Radiation pulse time	τ ≈ 15 ns
Neutron yield (D-D)	$N \sim 10^8$

Table 3. Parameters of the switch.

Switching voltage	U ≤ 25 kV
Commutation current	I ≤ 200 kA
Switching/jitter time	τ ≤ 4 ns
Lifetime	$T \geq 10^6$ cycles

Table 2. Parameters of the KMK-7-30 condenser.

Capacity	C = 7 μF
Nominal voltage	U = 30 kV
Inductance	L ≤ 10 nH
Maximal current	I ≤ 350 kA
Mass	m = 70 kg
Lifetime	$T \geq 10^6$ cycles

Table 4. Parameters of the PF-0.2 installation.

Energy store	W ≅ 200-300 J
Bank capacity	C = 1 μF
Charging voltage	U ≤ 20 kV
Maximal current	I ≤ 100 kA
1-st quarter-period	1/4T ≅ 400 ns
Radiation pulse time	τ ≈ 5 ns
Neutron yield (D-D)	$N \leq 10^7$

Sci. Prod. Corp. "Plasma", Ryazan. The research work in order to have further improvement of the device parameters is now going on, so one can consider our operations with the "EVOLUTA" as the successful test experiment [1]. Up today attained parameters of the switch are presented in Table 3.

The photograph of the PF-3 installation with the exception of its principal part – the DPF chamber – is shown in Fig. 1. Each of the two pseudo spark switches is set onto its condenser. The capacity bank is connected with the current collector by 24 short pieces of cable. There is a chamber seat in the heart of the collector. The construction gives us an opportunity to employ changeable DPF chambers intended for various applications such as: neutron generation, hard X-ray generation, soft X-ray generation, and so on. A number of different DPF chambers we use in our experiments are designed within our collaboration with the Institute of Automatics, Moscow. The scheme of a soft X-ray chamber is shown in Fig. 2 as an example. It is useful to mention that the soft X-ray experiment [1, 2] together with other results have given us the opportunity to test our installation operating with the high repetition rate. It turned out that the device designed for soft X-ray micro-lithography, being equipped with a chamber cooling system is able to operate with the rep rate up to 10 Hz.

Each small chamber we used to deal with is constructed as a closed non-partitionable block. In order to apply our installation to the INCO-COPERNICUS programme fulfillment we have taken a decision to open one of our chambers. The photograph of the opened DPF chamber and the chamber intended for a hard X-ray generation is shown in Fig. 3. The

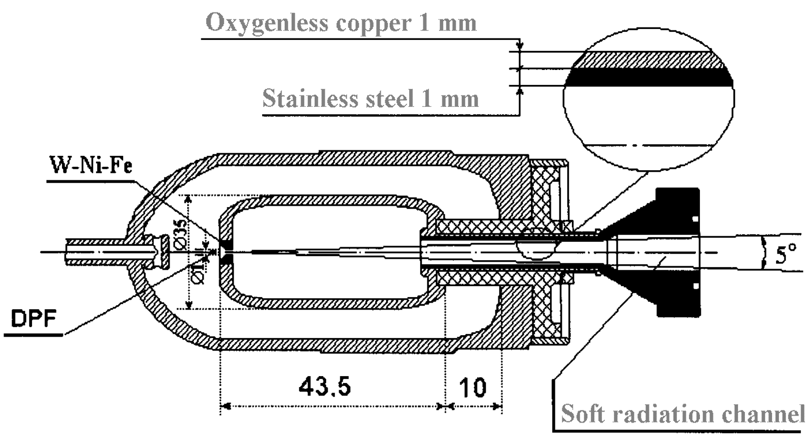

Fig. 2. Soft X-ray DPF chamber.

Fig. 1. Photo of the installation PF-0.2.

Fig. 3. DPF chamber intended to generate hard X-ray radiation (on the left) and the opened DPF chamber.

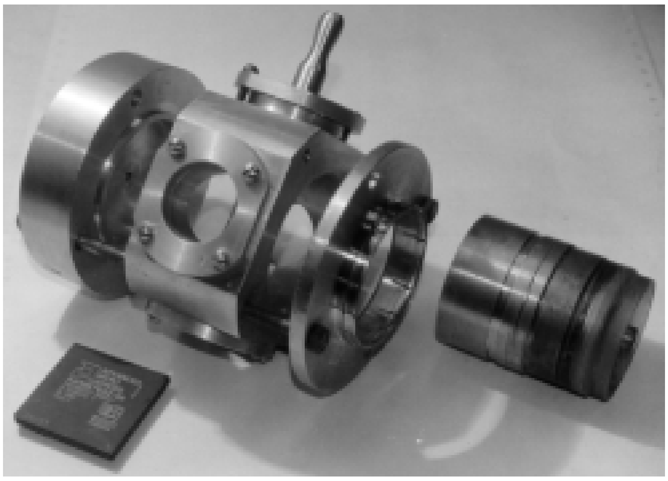

Fig. 4. The construction system for opened DPF chamber.

Fig. 5. Photo of the PF-0.2 installation.

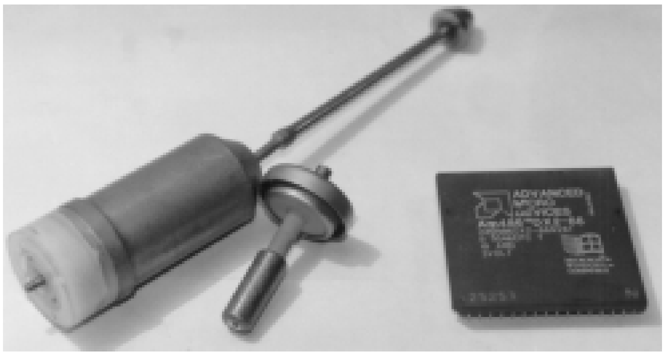

Fig. 6. Photo of the PF-0.2 chamber.

photo of a special construction system designed to be used for material sciences with the opened DPF chamber at the PF-3 installation is presented in Fig. 4. The samples holder is placed inside the construction, so it is easy to locate any metallic or non-metallic sample in order to irradiate this one by the fast ions and hot plasma jet moving from the DPF anode to its cathode. The disassembled nature of the construction makes it possible also to locate any sample at the central part of the chamber anode to irradiate the sample by a strong relativistic electron beam generating inside the plasma focus device.

PF-02 installation

The micro-installation PF-02 was initially designed for the purpose to create a miniature neutron generator based on a DPF phenomenon. We have made for this chamber a number of changes which give us opportunities to use it at materials sciences (micro-instrumentation treatment at the workplace), and as a source of both hard and soft X-ray radiation. The parameters of the installation are presented in Table 4. The PF-02 device is shown in Fig. 5. In Fig. 6 a photo of micro DPF chamber accompanied by its fragment – the anode-insulator assembly – is presented.

The installation presented in Fig. 5 is assembled with the energy capacitor and the switching system as a single block, but it is important to note that the possibility to bring out the chamber from the energy set at a distance about 30 cm by means of a flexible cable is provided. This feature together with the installation portability make it possible to apply the described here pulse radiation generator for the various applications, such as: plasma diagnostics, neutron detector calibration, material structure analysis, radiobiology, medicine, and so on.

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